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NURSERY FERTILIZATION OF DOUGLAS-FIR SEEDLINGS with different forms of nitrogen

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ABSTRACT

Three commercial fertilizers--ammonium sulfate, calcium nitrate, and urea--were tested to determine the relative values of ammonium, nitrate, and urea as nitrogen sources for Douglas-fir seedlings. The seedlings were grown at a forest tree nursery in western Washington and the fertilizers were broadcast at 50 pounds nitrogen per acre in May and again in September. Seedling growth in the nursery and outplanting performance of the trees fertilized with nitrate and urea were essentially the same and superior to the ammonium treatment.

Keywords: Forest nursery fertilization, Douglas-fir seedlings, ammonium sulfate, calcium nitrate, urea, survival, height growth, ovendry weight.

INTRODUCTION

Millions of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings are annually produced in forest tree nurseries and outplanted throughout the Pacific Northwest. To maximize production, nurseries in the region apply intensive cultural practices, fertilization being one of the most common.

Presently, the nurseries follow different fertilization regimes which vary basically in the amount and form of nitrogen. Although amounts of nitrogen fertilizer applied are logically based upon the fertility of the nursery soil, choice of the nitrogen source has been largely empirical.

Experiments with herbaceous plants (*3, 5, 6*) and nutritional studies with seedlings of some coniferous species (*4, 9, 14*) have shown that the source of nitrogen supply greatly affects both the growth and the chemical composition of plants. Such information, however, is not available for Douglas-fir, although many nitrogen fertilization studies have been made on the species. Similarly, information is still lacking on the effects of nitrogen source applied in the nursery on outplanting performance of Douglas-fir. Changes in growth and chemical composition of the trees due to nursery fertilization treatments could substantially affect the success of regeneration. Recent field and laboratory studies point to the importance of nursery nutrition to survival and growth of outplanted Douglas-fir trees (*2, 7*). In addition, results of other studies (*11, 13*) indicate that different fertilization regimes may alter acceptability of Douglas-fir trees to deer. The impact of these potential differences could be most important in areas where deer browsing is a problem.

This paper reports effects of nursery fertilization with ammonium, nitrate, and urea nitrogen fertilizers on growth and survival of Douglas-fir seedlings. It is part of a larger study on effects of nitrogen nutrition in the nursery on the morphology and chemical composition of the seedlings and deer preference for the fertilized trees.

MATERIALS AND METHODS

One-year-old Douglas-fir seedlings grown from a low-elevation seed source at the Webster State Forest Nursery near Olympia, Wash., were selected in March 1967. The seedlings, in nine 4- by 165-foot nursery beds, were fertilized at sowing in April 1966 with the nursery's standard ammonium phosphate-sulfate fertilizer (16-20-0) at the rate of 300 pounds per acre. Average seedling height was about 8 centimeters, and stocking within all beds was relatively uniform with an average of 45 seedlings per square foot.

Three commercial fertilizers in granular form were tested. These fertilizers, ammonium sulfate, calcium nitrate, and urea, supplied nitrogen in the form of a cation, an anion, and an undissociated molecule, respectively. Each fertilizer treatment was replicated three times, and treatments were assigned to the nine beds at random. In May and again in September, the fertilizers were broadcast with a tractor-drawn spreader at the nursery's standard rate of 50 pounds nitrogen per acre. In both the ammonium sulfate and urea treatments, seedlings received the assigned nitrogen treatment plus calcium sulfate containing calcium equivalent to that in the calcium nitrate treatment. Thus, the sulfate ion was the only variable among the three treatments. This imbalance was not considered serious, since the sulfate level was apparently adequate in the nursery soil and because no special need of it by Douglas-fir is indicated in the literature. Furthermore, it was impossible to completely balance the treatments.

Response to fertilization was evaluated while seedlings were still in the beds. Color of the trees was compared visually; and, at bimonthly intervals, seedling heights were determined by measuring 30 trees chosen at random from each replication.

In November, sample trees from each of the nine beds were lifted by hand and tied in bundles of five seedlings each. Fifteen and eight representative bundles of seedlings from each treatment were used for subsequent determinations of dry weights and outplanting performance, respectively.

Dry weights were determined in the laboratory. Seedlings were washed free of soil and severed at the root collar. Roots and tops from each bundle were then dried to constant weight in a forced-air oven at 65° C.

Effects of treatments on survival and growth of outplanted stock were evaluated in an exclosure near the nursery. The test area had droughty soils and was occupied by a dense cover of forbs and grasses; it was selected to provide a severe comparison among treatments. Seedlings were randomized

at 3- by 3-foot spacing in four blocks containing 10 trees of each treatment. The trees were examined frequently, and height growth and survival were determined after the first and second growing seasons.

RESULTS

Seedling Response to Treatment

Visual color comparisons in the nursery indicated treatment differences between seedlings. Trees fed nitrate or urea were darker green than those of the ammonium treatment. Color differences were evident approximately 3 weeks after the first fertilization in May and continued essentially unchanged until lifting in November.

Over the growing season, three main stages of seedling height growth were evident: (a) very rapid growth from May to July, (b) rapid growth from July to September, and (c) a leveling-off stage from September to November (fig. 1). Seedlings, therefore, put on virtually all of the season's height growth

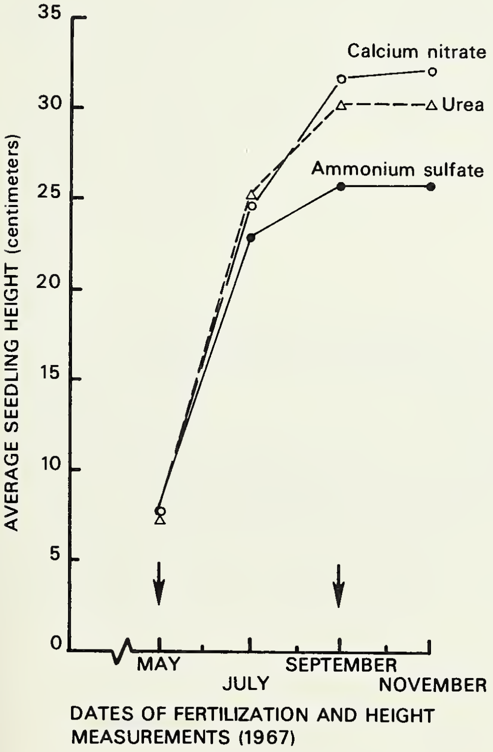

Figure 1.--*Effect of nursery fertilization with different forms of nitrogen on height of Douglas-fir seedlings. (Arrows signify fertilization dates.)*

during the 4 months following the first fertilization. During this period, average rates of growth, and in turn final heights, varied by treatment. Thus, at lifting, nitrate and urea, which promoted the fastest growth, produced the tallest seedlings, while ammonium, which was associated with the slowest growth, produced the shortest trees (table 1).

Ovendry weights of shoots but not of roots were affected by treatment, and effects paralleled those observed with seedling heights (table 1). Thus, ovendry weights of nitrate and urea shoots were essentially the same and exceeded those from the ammonium treatment. This indicates that differences in height growth were due to treatment effects on production of dry matter in the shoots.

Table 1.--*Effect of nursery fertilization with different forms of nitrogen on growth of Douglas-fir seedlings*[1/]

Nitrogen-fertilizer treatment	Ovendry weight		Height
	Shoot	Root	
	- - - *Grams* - - -		*Centimeters*
Ammonium sulfate	2.5 a	1.1 a	25.9 a
Calcium nitrate	3.5 b	1.2 a	32.2 b
Urea	3.3 b	1.2 a	30.4 b

[1/] Fertilizers were applied to the seedlings in the nursery at 50 pounds of nitrogen per acre in May and again in September, and seedlings were lifted in November 1967.

Ovendry weight and height values are, respectively, averages of 75 and 90 seedlings each.

Means in each column followed by the same letter(s) do not differ significantly at the 5-percent level, using Tukey's test (*15*).

Outplanting Survival and Growth

Survival and growth were generally poor despite careful lifting, handling, and planting of the stock (table 2). This poor performance was probably a reflection of the severe environment of the test area.

Nearly 25 percent of the seedlings died the first year, and many more failed to survive the second. Urea treatments survived best during both years; and after the second season, survival was intermediate with nitrate- and lowest among ammonium-treated trees.

Seedlings grew little either year regardless of treatment. After two growing seasons, the trees averaged only about 10 centimeters taller than at planting.

Table 2.--*Effect of nursery fertilization with different forms of nitrogen on survival and height growth of outplanted Douglas-fir seedlings*[1/]

Nitrogen-fertilizer treatment	Survival		Height growth	
	First season	Second season	First season	Second season
	- - - - *Percent* - - - -		- - - *Centimeters* - - -	
Ammonium sulfate	78 ab	33 b	5.0 a	5.5 a
Calcium nitrate	65 b	48 ab	5.4 a	4.0 a
Urea	83 a	60 a	4.8 a	5.0 a

[1/] Fertilizers were applied to the seedlings in the nursery at 50 pounds of nitrogen per acre in May and again in September, and seedlings were lifted in November 1967.

Fertilized seedlings were outplanted in an exclosure, and survival and height growth were determined in September 1968 and 1969.

Survival percents are based upon 40 seedlings of each treatment, and height growth values are averages for surviving seedlings of each treatment.

Means in each column followed by the same letter(s) do not differ significantly at the 5-percent level, using Tukey's test (*15*).

DISCUSSION AND CONCLUSION

Data from the nursery, laboratory, and exclosure indicate definite differences in the value of the three different forms of fertilizer nitrogen for Douglas-fir seedlings. Under conditions of the experiments, responses to urea and nitrate were essentially the same, and both fertilizers were superior to ammonium. Known differences between the three nitrogen fertilizers are in effects on soil pH, losses through leaching and volatilization, susceptibility to transformations through microbial and enzymatic action, fixation by soil particles, and availability characteristics. These differences and our limited studies do not indicate a definite basis for the observed differential effects caused by the nitrogen sources. Clearly, satisfactory explanation of results can only be obtained through sophisticated nutritional studies dealing with all aspects above plus detailed analysis of the chemical makeup of seedling tissues and photosynthetic efficiency of foliage during the experiments.

It is not possible to make meaningful comparisons with results of other studies in the literature. With both herbaceous and conifer species, earlier experiments dealt mostly with evaluation of ammonium and nitrate nitrogens, with few reporting on comparative effects of the three nitrogen sources. In addition, these experiments often gave conflicting results, with ammonium (*9, 16*), nitrate (*4, 6*), or urea (*14*) as the favored nitrogen source. Still other studies showed little differences between the nitrogen sources (*8*), or differences depending upon nitrogen level (*12*), pH of the rooting medium (*1*), and age of the test plant (*10*). Obviously, therefore, the most suitable nitrogen source for a plant species would depend upon many factors which should first be identified and then studied carefully under actual conditions of its growth.

We believe that differences among treatments in our results are of sufficient magnitude to justify consideration in nursery management practice. In addition, because of the complexity of the factors involved, we emphasize the need for on-the-site investigations at different nurseries to determine the best fertilization regime for Douglas-fir.

LITERATURE CITED

1. Addoms, Ruth M.
   1937. Nutritional studies on loblolly pine. Plant Physiol. 12: 199-205.

2. Anderson, Harry W., and Stanley P. Gessel.
   1966. Effects of nursery fertilization on outplanted Douglas-fir. J. Forest. 64: 109-112.

3. Arnon, D. I.
   1939. Effect of ammonium and nitrate nitrogen on the mineral composition and sap characteristics of barley. Soil Sci. 48: 295-307.

4. Durzan, D. J., and F. C. Steward.
   1967. The nitrogen metabolism of *Picea glauca* (Moench) Voss and *Pinus banksiana* Lamb as influenced by mineral nutrition. Can. J. Bot. 45: 695-710.

5. Kirkby, E. A.
   1968. Influence of ammonium and nitrate nutrition on the cation-anion balance and nitrogen and carbohydrate metabolism of white mustard plants grown in dilute nutrient solutions. Soil Sci. 105: 133-141.

6. _______ and K. Mengel.
   1967. Ionic balance in different tissues of the tomato plant in relation to nitrate, urea, or ammonium nutrition. Plant Physiol. 42: 6-14.

7. Krueger, Kenneth W.
   1967. Nitrogen, phosphorus, and carbohydrate in expanding and year-old Douglas-fir shoots. Forest Sci. 13: 352-356.

8. Leyton, L.
   1952. The effect of pH and form of nitrogen on the growth of Sitka spruce seedlings. Forestry 25: 32-40.

9. McFee, W. W., and E. L. Stone, Jr.
   1968. Ammonium and nitrate sources for *Pinus radiata* and *Picea glauca*. Proc. Soil Sci. Soc. Amer. 32: 879-884.

10. McKee, H. S.
    1962. Nitrogen metabolism in plants. 728 p. Oxford: Clarendon Press.

11. Mitchell, H. L., and N. W. Hosely.
1936. Differential browsing by deer on plots variously fertilized. Black Rock Forest Pap. 5: 24-27.

12. Nielsen, K. F., and R. K. Cunningham.
1964. The effects of soil temperature and form and level of nitrogen on growth and chemical composition of Italian ryegrass. Proc. Soil Sci. Soc. Amer. 28: 213-218.

13. Oh, John H., Milton B. Jones, William M. Longhurst, and Guy E. Connolly.
1970. Deer browsing and rumen microbial fermentation of Douglas-fir as affected by fertilization and growth stage. Forest Sci. 16: 21-27.

14. Pharis, Richard P., Robert L. Barnes, and Aubrey W. Naylor.
1964. Effects of nitrogen level, calcium level and nitrogen source upon the growth and composition of *Pinus taeda* L. Physiol. Plant. 17: 560-572.

15. Snedecor, George W.
1961. Statistical methods applied to experiments in agriculture and biology. 534 p. Ames: The Iowa State Univ. Press.

16. Swan, H. S. D.
1960. The mineral nutrition of Canadian pulpwood species. I. The influence of nitrogen, phosphorus, potassium, and magnesium deficiencies on the growth and development of white spruce, black spruce, jack pine, and western hemlock seedlings grown in a controlled environment. Pulp and Paper Res. Inst. Can., Tech. Rep. No. 168.

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